THE EFFECT UPON ATMOSPHERIC TRANSPARENCY OF THE ERUPTION OF KATMAI VOLCANO.

By Prof. HERBERT H. KIMBALL, Mount Weather, Va.

Katmai Volcano is in the Aleutian Range, Alaska, latitude 58° N., longitude 155° W., approximately. (See map, p. 155.) On the afternoon of June 6, 1912, it suddenly became explosively eruptive, continued in a state of great activity for about three days, and was reported to be still somewhat active at the end of October, 1912. A newspaper clipping from Seward, Alaska, dated January 16, 1913, states: "For the first time since its eruption on June 6, 1912, Mount Katmai and surrounding mountains are visible."

Brief descriptions of this eruption have already been published,[1] and we may expect an exhaustive report from a representative of the National Geographic Society in the near future.[2] The reader is referred to these for details of the eruption, which seems to have surpassed that of Krakatoa in 1883 in the quantity of material discharged into the atmosphere, although the explosions were much less violent.

In the preparation of this paper data relative to the detonations that accompanied the eruption, the fall of ash that followed, and a hazy or smoky condition of the atmosphere that prevailed in British Columbia and the United States during the latter part of June, 1912, have been derived from the following sources:

1. The descriptive papers already referred to.
2. Extracts from the meteorological reports for June, 1912, of the cooperative observers of the Weather Bureau.
3. Replies to a circular letter dated December 7, 1912, addressed to officials in charge of Weather Bureau stations and requesting copies of all notes made in the Daily Local Record since June 1, 1912, relative to the occurrence of any special hazy or smoky conditions of the atmosphere, or of unusually brilliant colors at sunrise or sunset.
4. Extracts from the meteorological reports of observers in British Columbia, which were kindly forwarded to the Chief of the Weather Bureau by the Director of the Meteorological Service of Canada.
5. Extracts from the logs of ships sailing on the North Pacific Ocean in June, 1912.
6. Replies to a circular letter of December 28, 1912, addressed to the members of the Astronomical and Astrophysical Society of America and requesting copies of any observational data they might have bearing upon the subject of diminished atmospheric transparency since June, 1912.

Detonations.—There is a wide range in the time at which the detonations were first heard at different places. At Seldovia, 155 miles from Katmai, explosions were heard before noon of the 6th. On board the steamship *Dora*, in Shelikof Strait, and only about 75 miles from Katmai on the afternoon of June 6, detonations were not heard until 1 p. m., and almost immediately afterwards a sheet of flame was seen to shoot from the volcano high into the air.

At Cordova, 360 miles from the volcano, explosions were first heard at 7 p. m., of June 6; at Copper Center, 450 miles distant, they were recorded as heard on June 7; while at Chicken, more than 600 miles distant, they were first heard at 2.30 p. m., of the 6th, and continued until 6 a. m., of the 9th, at intervals of two or three minutes for the first few hours, then some at longer intervals, and again some in quick succession.

At Cordova the detonations were described as resembling signal guns at five-second intervals, but varying in volume, and were not mentioned after 10 p. m., of June 7. At Seldovia they were last heard on the 10th.

If we take into account the difference in local time between Chicken, Alaska, and Shelikof Strait (13° in longitude corresponds to a difference of nearly one hour), then the time at which explosions were first heard at Chicken and on board the steamship *Dora* are in fairly close agreement, and we must conclude that preliminary explosions that were audible at Seldovia were not heard at either of these places.

At Kodiak, 100 miles from the volcano, peals of thunder attracted attention rather than volcanic explosions. Severe thunder storms appear to have accompanied the dense smoke cloud, and did not occur far from it, as none were mentioned at Seldovia. On the 7th, from the steamship *Dora*, then in Cook Inlet, the smoke cloud could be seen carried to the south and east by the prevailing northwest surface wind.

Earth tremors were reported at several places, but there were no destructive shocks.

Fall of volcanic ash.—At Amalik Bay, 15 miles southeast of the volcano, ashes fell to a depth of 55 inches. At Kodiak, 100 miles to the east, the depth was 10 inches. At Naknek, less than 100 miles to the northwest, the fall was 4 inches, while at Seldovia, 155 miles to the northeast, it was less than an inch.

Reports show that light falls of ash extended in latitude from Rampart, Alaska, latitude 65½° N., to Loring, Alaska, latitude 55½° N., and again in the State of Washington to latitude 48½° N. In longitude the fall extended from Nushagak, Alaska, longitude 158½°; to Chicken, Alaska, longitude 142°; to Loring, Alaska, longitude 131°, and in the State of Washington to longitude 122½°.

In this connection the notes made by Mr. J. E. Hissong, in charge of the Weather Bureau office at Tatoosh Island, Wash., are of special interest:

June 10. Light deposit of fine white ash found on southwest side of storm-warning tower at noon. Evidently carried by wind from volcanic explosions in southwestern Alaska.

June 11. No smoke or dust perceptible at station except a slight deposit on windows where rain drops strike.

June 12. No smoke or dust noticeable to-day. Yesterday's rain probably cleared the air.

June 13–14. During the evening of the 13th the air was filled with a very fine ash and smoke, a light deposit being noted on office furniture on the morning of the 14th.

At Olga, Wash., on June 10, the following note was made:

Haze. Volcanic ash, supposed to be from Alaska. All polished metal tarnished very quickly.

[1] Volcanoes in Alaska. Nat. Geog. Mag., August, 1912, v. 23, p. 824–832.
Dailey, I. M. Report of the Eruption of Katmai Volcano. Bull. Amer. Geog. Soc., September, 1912, v. 44, pp. 641–644.
McAdie, A. G. Recent Pacific Volcanic Eruptions and Atmospheric Phenomena. Meteorological Chart of the North Pacific Ocean, February, 1913.
McAdie, A. G. Taal, Asama-Yama, and Katmai. Bull. Seismol. Soc. Amer., v. 2, pp. 233–242.
Clark, George Archibald. The Katmai Eruption. Bull. Seismol. Soc. Amer., v. 2, pp. 226–229.

[2] Martin, George C. The Recent Eruption of Katmai Volcano in Alaska. Nat. Geog. Mag., February, 1913, v. 24, pp. 131–181.

Mr. Walter S. Adams contributes the following from the Mount Wilson Solar Observatory, Pasadena, Cal.:

The coelostat mirrors in the top of the 150-foot tower were freshly silvered about July 25. On August 3 the coats were very bright and fresh, but on August 5 we found them covered with minute round black spots, which under a microscope were seen to be actual discolorations in the silver film. The larger spots had a nucleus but the smallest spots had none. I have never observed such a phenomenon before, and the appearance was in every way similar to the effect which would be produced by dropping fine dust impregnated with sulphur upon the silver film. The mirrors were uncovered to the sky and in use on August 3 and 4.

Much more complete information relative to the depth of the fall of ash and the area covered will be found in the report referred to above, by Mr. George C. Martin, who spent the summer in the vicinity of the volcano.

Haze and smoke.—The data indicates that a hazy or smoky period set in over British Columbia on June 6 to 8, and in the northwestern part of the United States on June 8 to 10, and continued until June 11 to 12, at the same time gradually extending eastward. A second hazy or smoky period, preceded by volcanic fumes at Sitka, Alaska, on June 15, set in over British Columbia on June 18 to 20, over the northwestern part of the United States on about the same dates, gradually extended eastward and southward, and diminished in intensity before the end of the month, especially in the States west of the Rocky Mountains.

The data also indicate that the haze or smoke may be attributed to three different causes, as follows:

1. The general meteorological conditions, which are usually especially favorable for the formation of haze on the rear of areas of high pressure.

2. Smoke from forest fires. The Chief of the United States Forest Service states that extensive forest fires prevailed in the Yukon Territory, Canada, south of Dawson, during the latter part of May, 1912, in the upper Fraser country, British Columbia, about June 6, and near Golden, British Columbia, between June 11 and 26. There were no reports of serious forest fires in the United States in June, 1912.

3. Smoke or dust from the eruption of Katmai Volcano.

It is impossible to completely separate the effects of these three causes, but it seems evident that the haze and smoke in British Columbia on June 9–10, which in several places was accompanied by sulphur fumes, was at least in part of volcanic origin. The same may be said of the haze and smoke that was particularly pronounced over the States of Washington, Montana, and Wyoming on the same dates, coming as it did at about the same time as the fall of volcanic ash in Washington. The description which follows by Mr. R. Frank Young, in charge of the Weather Bureau office at Helena, Mont., is indicative of the unusual character of the haze:

June 10. A light smoke was noticeable in the upper air by noon, which increased during the day, and almost obscured the disk of the sun for about an hour before sunset, and caused a pronounced red glare in the western sky.

June 11. Light smoke from an unknown cause hung over this vicinity during the day.

June 12. Light smoke not visible in the evening, although the air had a smoky appearance during the forenoon.

The following notes were made by Mr. E. R. Miller, in charge of the Weather Bureau office, Madison, Wis.:

June 8. High haze in the form of streaks, rapidly moving wave systems, and clotted forms observed from 11 a. m., until late in the afternoon. The wave systems of from 3 or 4 to 12 or 15 waves, well spaced and straight, but not more than 8° to 10° from end to end, were moving rapidly from the west, or from west, 10° north.

June 9–10. High haze continued, but became denser, so that definite forms were more difficult to identify. Solar halo observed at 3.30 p. m. of the 10th.

In a letter of later date Mr. Miller states that the haze clouds were unlike anything he had ever seen before, and that his observation was confirmed by several residents of Madison.

On June 8 the Cooperative Observer at Elden, Mo., recorded "Hazy clouds."

The appearance of the haze as described at Madison on June 9 and 10 was much as it appeared at Mount Weather on June 10 and 11, except that no preliminary wave forms were observed at the latter place. This may have been due to the fact that cumulus clouds covered the sky on the afternoon of the 9th, and on the morning of the 10th the haze was already dense.

While the appearance of the haze was such as to occasion discussion among the members of the Mount Weather staff, it was the consensus of opinion that it did not differ materially from the haze frequently observed on the rear of an area of high pressure, except in its unusual density, and it was not until it had persisted practically continuously for some weeks that it was thought necessary to try to connect it with other than meteorological causes.[1]

It may also be said that while there appears to be abundant proof from notes made by observers on their meteorological records that haze of an unusual character overspread the United States during the latter part of June, 1912, only a small percentage of Weather Bureau observers made any mention of it.

Madison, Wis., is about 3,000 miles from Katmai, and the difference in longitude, 66°, is equivalent to about 4½ hours in time. If we suppose the first violent eruption to have occurred at 1.30 p. m., of June 6, the time that elapsed before the haze was observed at Madison was 41 hours; and if the haze was of volcanic origin its rate of translation was about 73 miles per hour. This is no greater than was observed after the eruption of Krakatoa, and does not equal the highest velocities that have been measured by means of balloon ascensions and observations of meteor trails in those high levels to which volcanic dust is raised by violent eruptions.[2]

The volcanic ash that fell in the State of Washington on June 10–13 was either brought in by the slower surface winds (1,450 miles in 90 hours=16 miles per hour), or else it consisted of the coarser particles that made up the high haze, and which would be the first to reach the ground. The latter seems the more probable assumption, since rain would very quickly clear the lower atmosphere of solid particles of this character, as was observed to be the case at Tatoosh Island on June 12.

That the haze that overspread the United States after June 18 was of much the same character as that of June 8 to 10 is indicated by the following notes by Mr. H. A. Frise, in charge of the Weather Bureau office at Sheridan, Wyo.:

June 19. A thin veil of high cloud has covered the sky all day, giving it a dull-gray color, but not shutting out sunshine.

June 20. The veil of high cloud, while diminishing the brightness of the sun and probably preventing an early record by the recorder, has not interfered with a record for the remainder of the day. The sun at 7 p. m., local time, was easily viewed with the unaided eye, and appeared near the horizon as a large white disk.

June 21. The sun has appeared as a large bright disk not painful to view—in fact, easily viewed by the unaided eye after 7 p. m. No red colors have appeared at the sun or in the region surrounding it. The sky up to 8.30 p. m. in the northwest was white with light entirely free from the reddish tinge so often seen after a windy day.

June 22. The high cloud veil has reduced the sun's brilliancy considerably. The effect in screening the sun's rays is noticeable, but it is quite probable that a large part of the community has not observed the peculiar conditions.

[1] See Bulletin of the Mount Weather Observatory, v. 5, p. 161.
[2] Report of the Krakatoa Committee of the Royal Society, p. 334.

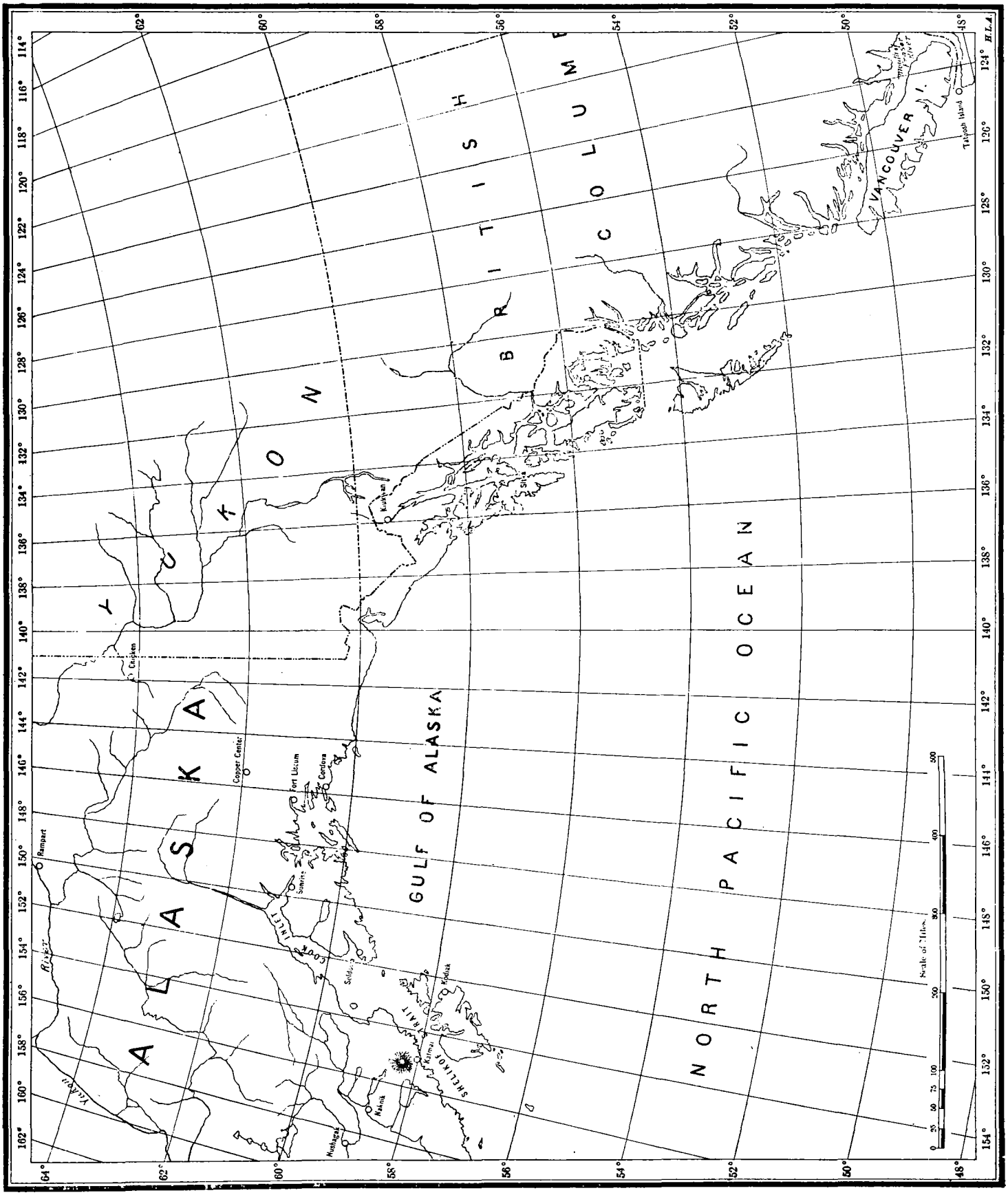

CHART OF ALASKA AND ADJACENT PORTIONS OF BRITISH COLUMBIA, SHOWING EXTENT OF DEPOSITS OF VOLCANIC ASH BY THE ERUPTION OF MOUNT KATMAI ON JUNE 6, 1912.

June 23. The high veil of thin cloud persists, but the sunshine recorder has not refused to give a full day's record. Moonlight has not been interfered with, nor has it revealed the presence of a veil-like cloud, as has sunlight.

The following description by Mr. Frank Jermin, in charge of the Weather Bureau office at Alpena, Mich., is also significant:

June 23–29. This period was remarkable for the continual presence of haze in the upper strata of the atmosphere. It could be plainly seen, and was present only in the higher strata. Also, it was continuously present, except that on the 26th and 27th it was seen only in the morning.

The absence of records of haze or smoke in the northwestern part of the United States between June 11 and 18 may perhaps be attributed to the general rains that then prevailed in that section. At no time was haze or smoke so prevalent in the Southern as in the Northern States, and in general it was everywhere recorded less frequently in July than in June.

It may be well to call attention to a remarkable solar halo for the season of the year that was observed at Tatoosh Island, Wash., on June 17:

Smoke on the horizon became less dense during the afternoon. Very distinct 22° solar halo observed from 8 a. m. until 6.30 p. m. About 2 p. m. a complete parhelic circle passing through the sun parallel to the horizon was noted. This circle was white and rather faint, but formed bright parhelia at its intersections with the halo. The maximum brilliancy occurred at 2.30 p. m., at which time the red band of the halo was unusually distinct. About 3 p. m., it began to fade, and at 5 p. m. the white circle had disappeared, although traces of the parhelia were noticeable. From 2 p. m. to 3 p. m. the sky was apparently clear except for a single wisp of cirrus. The atmosphere near the horizon, however, was slightly smoky or hazy.

Diminished atmospheric transparency in 1912.—The pyrheliometric measurements made at Mount Weather show a marked decrease in solar radiation intensities, commencing with June 10, 1912, and at the same time the polarization measurements indicate a decrease in the percentage of polarization of skylight. This is made clear by a comparison of the data for certain months of the years 1911 and 1912 in Table I. Furthermore, the average intensity of solar radiation with the sun at zenith distance 60° during the latter half of 1912 was only 83 per cent of the average for the corresponding period in previous years.

This subject will be discussed more fully in a paper in the Bulletin of the Mount Weather Observatory, volume 5.

TABLE I.—*Comparison of sky polarization and solar radiation data for Mount Weather, Va., during the months of May to December, inclusive, 1911 and 1912.*

Period.	Percentage of polarization of skylight.				Maximum radiation.					
	1911		1912		1911			1912		
					Air mass.			Air mass.		
	Max.	Min.	Max.	Min.	1.0	1.5	2.0	1.0	1.5	2.0
May	66	36	72	34	1.32	1.10	1.06	1.42	1.27	1.19
June 1–9	.....	.....	67	54	1.36	1.22	1.12	1.42	1.36	1.24
June 10–30	72	47	64	14	1.48	1.37	1.27	1.25	1.19	1.05
July	74	31	47	13	1.47	1.37	1.31	1.24	1.05	0.96
August	76	44	41	23	1.39	1.33	1.23	1.08	1.02	0.86
September	75	49	59	35	.....	1.35	1.29	.....	1.14	1.05
October	78	59	51	32	.....	1.47	1.39	.....	1.34	1.24
November	[1] 73	[1] 53	57	43	.....	.....	[1] 1.39	.....	.....	1.24
December	[1] 71	[1] 68	61	39	.....	.....	.....	.....	.....	1.33

[1] Data for the year 1908.

In a recent letter the director of the Meteorological Service of Canada inclosed pyrheliometric readings made at Toronto in 1912. Those for June 10 and 13 showed no evidence of decreased solar radiation intensity, but the decrease was pronounced in the readings for July 1.

Astronomical observations.—It seemed probable that a change in atmospheric transmissibility for solar radiation of the magnitude indicated above would affect astronomical observations, and especially astronomical photography. The circular letter of December 28, 1912, already referred to, was therefore prepared and addressed to all members of the Astronomical and Astrophysical Society of America.

A majority of the replies were to the effect that no data had been obtained bearing directly upon the subject, but a goodly number of astronomers had observed the decreased atmospheric transparency, and the data contributed by them will be divided for convenience of discussion into four classes, as follows: (*a*) Observations of the general atmospheric conditions; (*b*) determinations by some instrumental method of the relative atmospheric transparency; (*c*) astronomical photography; (*d*) twilight colors.

Under (*a*) we can not do better than to quote from the reply of John R. Eastman, professor of mathematics, United States Navy (retired), and dated Andover, N. H., January 3, 1913.

The first unusual peculiarity about the sky was noticed about June 13. When there were few or no clouds the sky presented an appearance that recalled conditions that I had seen many times in New England, occurring from five to eight hours before the beginning of a severe northeast snow-storm. At first it was thought to be the effect of smoke from distant forest fires, but there was no smell of smoke and the density of the opacity did not appear to increase towards the horizon; moreover, the color did not have the faint yellow tint of smoke haze. At times one could look at the sun without discomfort. During the latter part of June I should estimate the transparency of the sky at about 80 or 85 per cent of the normal.

* * * * *

For a period of nearly three weeks after the middle of June there was a noticeable diminution in the growth of nearly all farm and garden crops in this vicinity, and the ripening of such crops was materially delayed in the autumn.

The following is from Mr. Walter S. Adams, Mount Wilson Solar Observatory, Pasadena, Cal.

We observed a very marked diminution in the atmospheric transparency of the sky during the past summer. On certain days I should think it might have amounted to 10 per cent. It took the form of a very hazy white sky, which gave a distinctly yellow color to the sun, and at night produced a distinct diminution in the brightness of the stars.

Mr. John Tatlock, New York City, writes under date of January 3, 1913, as follows:

The past six months have been abnormal in New York as regards weather, and the decrease in atmospheric transparency has been a marked feature. I began to notice it last July, my attention being called to the fact that we had no clear atmosphere after summer storms, as is usually the case. This fall, as near as I can recollect, we have had no clear and chill October weather accompanied by a brilliant atmosphere.

Among others who report an apparent decrease in atmospheric transparency are the following:

G. W. Hill, West Nyack, N. Y.; Charles P. Oliver, Agnes Scott College, Decatur, Ga.; Garrett P. Serviss, Brooklyn, N. Y.; W. J. Humphreys, United States Weather Bureau, Washington, D. C.; Anne Sewell Young, John Payson Williston Observatory, South Hadley, Mass.; George E. Mellish, Madison, Wis.

Under (*b*) evidence of decreased atmospheric transparency is submitted by two independent observers at Yerkes Observatory, Williams Bay, Wis.—Mr. Oliver J. Lee and Mr. Frederick Slocum. Mr. Lee writes that the observations submitted by him are based on visual estimates of the transparency, *1* representing the lower limit for spectrographic work and *5* representing a brilliant transparent night. The estimates were made a half dozen times or

more each night when work could be done, which averaged 7.3 nights per month. He further states that all observers using the Bruce spectrograph during the past summer noted that exposure times had to be lengthened. The observers besides Mr. Lee were Prof. E. B. Frost, Mr. S. B. Barrett, and Prof. S. A. Mitchell.

TABLE 2.—*Monthly averages of atmospheric transparency as estimated at the Yerkes Observatory, Williams Bay, Wis.*

Month.	1910		1911		1912		$\frac{1910+1911}{2}-1912$	
	Lee.	Slocum.	Lee.	Slocum.	Lee.	Slocum.	Lee.	Slocum.
January	2.7	.....	2.8	.....	3.3	.....	−0.5	.....
February	2.1	.....	3.2	.....	3.3	.....	−0.7	.....
March	2.5	.....	2.7	.....	2.8	.....	−0.2	.....
April	2.3	2.4	2.8	2.6	2.7	2.2	−0.1	+0.3
May	2.4	2.7	2.4	2.5	2.2	2.2	+0.2	+0.4
June	2.3	2.3	2.2	2.9	2.0	2.1	+0.2	+0.5
July	2.7	2.8	2.4	2.6	1.6	2.1	+1.0	+0.6
August	2.0	2.3	3.0	2.8	1.6	2.2	+0.9	+0.4
September	2.4	2.6	2.8	2.9	2.5	2.0	+0.1	+0.8
October	2.8	2.5	2.4	2.75	2.6	2.4	±0.0	+0.2
November	3.6	.....	2.3	.....	2.2	.....	+0.8	.....
December	3.0	.....	2.7	.....	2.3	.....	+0.5	.....
Averages	2.57	2.51	2.64	2.72	2.42	2.17	+0.18	+0.45

Mr. Slocum writes as follows:

It has been my custom to estimate the transparency of the atmosphere at the time of each observation. This estimate was made by occulting the sun with the edge of the opening in the dome and noting the "milkiness" of the sky near the sun. If the sky were perfectly clear and blue right up to the edge of the sun, the transparency was recorded as 5. If, on the other hand, the sky were dull and the sun so weak that it was only just possible to make a photograph of it with the spectroheliograph, the transparency was called 1. From April to October I observe the sun on from 15 to 20 days per month.

The data in Table 2 are the monthly means of the transparency as estimated by the above two methods. It will be noted that both methods give decreased transparency in the latter part of 1912 as compared with corresponding months in 1910 and 1911, but they do not agree as to the month in which this decrease first became pronounced.

Similar results were obtained by Martin S. Brennan, St. Louis, Mo., in using a 6-inch refractor for examining sun spots, and particularly in viewing the binary star (61 Cygni) in the Swan, who estimated the decrease in transparency at about 10 per cent; by John T. Hedrick, S. J., at Georgetown College Observatory, Washington, D. C., who has been determining the brightness of variable stars by comparing them with neighboring stars, and who estimates the loss at 20 per cent; by Prof. Philip Fox, Dearborn Observatory, Evanston, Ill., who noted the general whiteness of the sky, the excessive faintness of stars of the lower magnitude, and the failure to observe nebulæ; and by Messrs. Abbot and Fowle in Algeria and California, whose spectro-bolometric measurements, as well as visual observations, showed a marked decrease in atmospheric transmissibility, first noted in Algeria on June 19, and at Mount Wilson, Cal., on June 21, and who estimate the decrease in solar radiation intensities at 20 per cent.

On the other hand, several observers have found that the "seeing" in the latter part of 1912 has been up to the average.

Under (*c*) we quote the following:

We are photographing through a 24-inch objective for stellar parallax, and have noted that the time of our exposure seemed to be increased.—JOHN A. MILLER, Swathmore College, Pa.

My observations were in connection with photographs of nebulæ and comets. July 10 and July 16 were the first photographs since April and magnitudes were fainter by ½ to 1 mag.

No other photographs were taken until October 3. From that time to November 6 the sky was below normal of transparency (18 nights). From November 6 to January 1 average transparency.—F. P. LEAVENWORTH, University of Minnesota.

Photographs of the solar spectrum show a marked decrease in intensity (apparently not less than 25 per cent). General haze, July to October, prevented observations. First noticed about July 1.—W. F. KING, director Dominion Observatory, Ottawa, Canada.

The above was also reported by J. S. Plaskett, of the same observatory.

The astronomical photographs have been very unsatisfactory this fall. I can not decide how much is atmospheric and how much due to slow plates.—JOEL H. METCALF, Worcester, Mass.

There was a marked decrease in atmospheric transparency throughout the summer. My observations at Yerkes are photographic, and the decreased transparency was very noticeable in the exposure time necessary.—Prof. S. A. MITCHELL, Williams Bay, Wis.

We detected a change in color of direct sunlight by spectrophotometric comparison with acetylene. First noted on June 11.—P. G. NUTTING, Bureau of Standards, Washington, D. C.

We have been making astronomical photographs for some years, mainly with a Cooke 5-inch lens, which has usually given us very large numbers of faint stars with exposures ranging from one to four hours. After June 1 most of this was carried on by students and by my associate, Mr. Drew, and I was continually disappointed that the usual exposures failed to show anything like the number of stars we had been getting before.—W. A. COGSHALL, Indiana University, Bloomington, Ind.

The data included under (*d*) will be considered in connection with other twilight observations.

Marvin sunshine recorder records.—The records from this well-known instrument require a correction for the time just after sunrise and just before sunset when the solar radiation is too weak to cause a record to be made. Instructions require that the adjustment be such that a record will be made when the disk of the sun can just be faintly seen through the clouds. Unfortunately, this necessarily leaves much to the judgment of the observer; and since the adjustment has to be changed with the season of the year, one can not be certain that the adjustment is such that the records are strictly comparable from year to year. However, the data given in Table 3 show that at 11 out of 15 stations the correction on clear days for early morning and late afternoon sunshine was greater during the last seven months of 1912 than during the corresponding months of 1911, or than during the first five months of 1912.

The stations selected are none of them in large cities where smoky conditions are to be expected, and they are fairly evenly distributed over the United States.

TABLE 3.—*Average time in hours and tenths that the sun's rays on clear days failed to affect the sunshine recorder immediately after sunrise and immediately before sunset.*

1911.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Amarillo, Tex.	0.2	0.3	0.3	0.4	0.7	0.5	0.7	0.7	0.6	0.4	0.2	0.3	....
Baker, Oreg.	.....	.....	0.9	1.2	1.2	1.3	0.9	0.6	0.5	0.6	0.7	0.7	....
Devils Lake, N. Dak.	1.1	1.0	1.0	1.0	1.5	1.7	1.5	1.6	1.4	1.1	1.0	0.8	....
Dodge City, Kans.	0.8	0.4	0.3	0.2	1.1	1.0	0.4	0.6	0.6	0.9	0.8	0.8	....
Fresno, Cal.	1.0	1.1	1.1	1.3	1.6	1.3	1.0	1.1	1.2	1.4	1.0	1.1	....
Jacksonville, Fla.	1.0	1.2	1.2	0.9	1.4	1.6	1.1	0.8	1.0	1.0	1.0	0.9	....
Lansing, Mich.	0.9	1.0	0.8	0.9	1.2	0.9	0.9	0.8	0.8	1.3	1.0	0.8	....
Lexington, Ky.	1.2	1.0	1.2	1.4	1.8	2.3	2.1	1.8	1.8	1.8	1.1	1.3	....
Madison, Wis.	1.1	1.0	1.2	1.5	1.5	1.3	1.3	1.4	1.6	1.1	0.9	1.3	....
Modena, Utah.	1.5	1.3	1.7	1.8	1.8	1.6	1.6	1.4	1.3	1.2	1.3	1.5	....
Mount Weather, Va.	0.4	0.4	0.8	0.7	0.7	1.0	1.2	1.1	1.1	0.9	0.9	0.9	....
Northfield, Vt.	0.9	0.9	1.0	1.1	1.3	1.3	1.4	1.3	1.0	1.3	0.9	1.1	....
North Platte, Nebr.	0.6	0.7	0.7	0.8	1.1	1.0	1.2	1.3	1.0	1.5	0.9	1.2	....
Yellowstone Park, Wyo.	0.9	1.0	1.0	1.2	1.3	1.2	1.2	1.1	1.0	0.9	0.9	0.9	....
Yuma, Ariz.	0.4	0.5	0.5	0.6	0.6	0.4	0.4	0.4	0.4	0.3	0.4	0.4	....
Mean	0.9	0.8	0.9	1.0	1.3	1.2	1.1	1.1	1.0	1.0	0.9	0.9	1.0

Average, January to May, inclusive, 1.0; average, June to December, inclusive, 1.0.

TABLE 3.—*Average time in hours and tenths that the sun's rays on clear days failed to affect the sunshine recorder immediately after sunrise and immediately before sunset*—Continued.

1912.

Station.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Amarillo, Tex.	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.2	0.4	0.3	0.4	0.4	....
Baker, Oreg.	0.9	1.1	0.9	0.9	1.5	1.9	2.1	0.8	0.9	0.9	0.7	0.8	....
Devils Lake, N. Dak.	0.9	1.3	1.5	1.4	1.5	1.9	2.4	2.4	1.9	1.2	1.2	1.3	....
Dodge City, Kans.	0.8	1.0	1.4	1.4	0.7	0.5	0.6	0.4	0.5	0.5	0.7	0.7	....
Fresno, Cal.	0.9	1.2	1.2	1.3	1.3	1.3	1.4	1.1	1.1	1.3	1.3	1.3	....
Jacksonville, Fla.	1.1	1.2	1.3	1.6	1.8	1.6	1.5	1.8	1.6	1.6	1.0	1.2	....
Lansing, Mich.	0.6	0.8	0.8	0.7	0.7	0.9	1.7	1.8	1.3	1.4	1.8	1.4	....
Lexington, Ky.	1.4	1.4	1.4	1.1	1.3	1.3	1.3	1.3	1.2	1.2	1.6	1.7	....
Madison, Wis.	1.0	1.1	1.2	1.5	1.9	3.0	2.5	1.9	1.6	1.4	2.3	2.0	....
Modena, Utah	1.5	1.5	1.6	1.7	1.8	1.7	1.9	1.8	2.0	0.9	0.8	0.8	....
Mount Weather, Va.	1.0	1.0	1.3	1.6	2.2	2.4	2.4	2.6	2.4	1.7	1.1	1.3	....
Northfield, Vt.	0.9	1.0	0.9	1.0	1.0	1.2	1.5	1.2	1.2	1.3	1.3	0.9	....
North Platte, Nebr.	1.3	0.9	1.2	1.7	1.5	1.4	1.2	1.3	1.4	1.3	1.6	1.3	....
Yellowstone Park, Wyo.	0.9	1.0	1.0	1.1	1.4	1.3	1.5	1.6	1.5	1.2	1.3	1.4	....
Yuma, Ariz.	0.5	0.5	0.6	0.6	0.5	0.5	0.6	0.5	0.6	0.6	0.5	0.6	....
Mean	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.4	1.3	1.1	1.2	1.1	1.2

Average, January to May, inclusive, 1.1; average, June to December, inclusive, 1.3.

Observations of twilight colors.—Careful observations of the color of the sky at about sunrise and sunset were made by the writer not only at Mount Weather, Va., during the summer, but also while on a visit to New Hampshire in September and on a western trip that included stops in Nebraska, Colorado, and New Mexico, in October and November, 1912. No twilight colors of unusual brilliancy were observed until the evening of October 13. Just after leaving Lincoln, Nebr., on a westbound train, it was noticed that the western sky was unusually red, and the following entry was made in my notebook:

After getting out of the city smoke the western sky was seen to have a brownish red color to a height of about 8°. There was a suspicion of a pink glow above this, but it did not last long. The red band grew narrower, and had disappeared by 6.30 p. m., central time.

On the morning of October 15 the Rocky Mountains were crossed through La Veta Pass in southern Colorado. The summit was reached just before dawn, and it was noted that the eastern sky was very red.

After reaching Santa Fe, N. Mex., on the evening of the same day, it was noted that whenever the sky was clear the twilight colors were brilliant, both morning and evening. Red shades predominated, but a purple or rose-colored glow that came on shortly after sunset was a feature. Usually, also, the sky near the place of sunrise or sunset was decidedly streaked, the bands appearing to lie horizontally. They lacked the fibrous appearance of cirrus clouds.

Upon my return to Mount Weather on November 11, 1912, my attention was at once attracted to the unusual brilliancy of the twilight colors both morning and evening, the red shades predominating, although the purple glow was frequently present. Upon inquiry of the Mount Weather staff it was learned that these brilliant colors had first been noticed about October 23.

The circular letter of December 7, 1912, was at once prepared and sent to officials in charge of Weather Bureau stations. Before it could be mailed, however, the central office was informed that Prof. A. G. McAdie, in charge of the Weather Bureau office at San Francisco, Cal., had sent out a similar letter to Weather Bureau observers on the Pacific coast, his attention having also been attracted to the unusually brilliant twilight colors. This action on the part of Prof. McAdie, as well as the extracts that follow from replies to circular letter of December 28 (*d*, under the classification of Astronomical Observations), confirms my own conclusion that the twilight colors during the fall months of 1912 were unusually brilliant.

EXTRACTS FROM REPLIES TO CIRCULAR LETTER OF DECEMBER 28, 1912.

Repeated note has been made of an unusual redness in the morning and evening twilight. Exact dates can not be given, but it was noticed as most conspicuous about the early part of September, continuing with decreasing intensity on into November. The records do not show that this was continuous, or that there were no intervening evenings when it was not seen; but my impression is that for a short time it was continuous.—A. THOS. G. APPLE, director Daniel Scholl Observatory, Lancaster, Pa.

One thing quite noticeable to all of us who have occasion to work at Mount Wilson was the red glow in the morning and evening sky at about the time of sunrise and sunset. It certainly was quite out of the ordinary, and we have wondered if it could have been connected with the Alaska eruption that occurred early in the summer.—F. H. SEARES, Mount Wilson Solar Observatory, Pasadena, Cal.

We have noticed that the sunsets were frequently moderately red, and we suspected that this slight redness was due to the dust particles projected into the atmosphere by the Alaskan volcanic eruption of last summer.—W. W. CAMPBELL, director Lick Observatory, Mount Hamilton, Cal.

The western sky during the early days of January [1913] was often decidedly red at sunset over a wide horizontal arc, decidedly in excess of the color ordinarily noted here.—R. H. TUCKER, Lick Observatory, Mount Hamilton, Cal.

A few mornings in October, 1912, I noticed the following somewhat unusual phenomenon: About three-fourths of an hour before sunrise there was a strong pinkish glow over nearly all the eastern half of the sky. It was particularly strong at 60° to 80° altitude—that is, high in the sky—and of quite a different appearance from the ordinary sunrise glow, besides occurring long before sunrise. There were few if any clouds, and no haze of ordinary varieties.—PAUL W. MERRILL, Lick Observatory, Mount Hamilton, Cal.

At night I have seen after sunset a ruddy glow somewhat similar to that following the Krakatoa explosion, but fainter, and which in conversation with others I have suggested might be due to the eruption in Alaska.—R. W. PRENTISS, professor of mathematics and astronomy, Rutgers College, New Brunswick, N. J.

At a few Weather Bureau stations it was noted from time to time during June, July, August, and September, 1912, that the twilight colors were unusually red. During October brilliant twilight colors were noted more frequently, and at a greater number of stations, and the climax in both brilliancy and frequency appears to have been reached in November. At only a comparatively small number of stations, however, was any note made of the twilight colors.

The following are quotations from a few of the more characteristic descriptions:

Yankton, N. Dak., June 23, 1912: Very red sunset.

The Dalles, Oreg., June 24, 1912: Brilliant red sky at sunrise.

Charleston, S. C., October 6, 1912: Western sky very red after sunset because of haze.

San Francisco, Cal., November, 1912: In general, the colors did not extend more than 15° north or south from where the sun set, and there appeared to be no difference in the two sides; possibly on the north side the color was more intense. The height of the colored region seldom exceded 10°. The point which struck me most in these observations was that the red color appeared to reach its maximum, not at the time of sunset, but 18 or 20 minutes afterwards.

Point Reyes Light, Cal., November, 1912: The sunsets reached a climax of brilliancy on the 20th, and there was a strong greenish glow for some time after sunset. As the sun descends close to the horizon the lower atmosphere takes on a smoky appearance. The coloring does not appear until a few minutes after the sun has set. Then there is a deep red on the horizon and to a height of about 12°, where it shades off into a greenish yellow, the extreme limit of which is about 25° in altitude. The colors extend about 40° north and south of the sun.

Sacramento, Cal.: During November, 1912, the sky in the west has been a lurid red, as if there were a destructive fire in progress. The area occupied by the light at sunset was about 25° altitude and 60° azimuth. At sunrise, in the east, it was probably about 15° and 40°, respectively. Less brilliant at the end of the month.

Fresno, Cal.: No unusual phenomenon of this character was observed until after November 10, 1912. On this date a very good general rain occurred and cleared the atmosphere of the dust, which gives it a very hazy appearance during the dry season. During the remainder of November a number of very beautiful sunsets were observed, which differed from the usual phenomenon in that the brilliant colorings were more widely and more evenly diffused than is common. Approximately 120° of the western horizon was colored, the hues reaching well toward the zenith and continuing with a brilliance more or less noticeable for fully an hour after sunset. The duration was an especial feature of the phenomenon. The reds were most conspicuous, but other colors in that portion of the spectrum, the yellows and oranges, which appeared first in order, were not much less so.

Santa Fe, N. Mex., December 29, 1912: The sunset glow this evening was especially brilliant. By 5.10 p. m. the entire western sky was rosy from 110° north to 90° south of the sunset point, and upward fully 65°. By 5.20 p. m. the colors had become brilliant red about the sunset point, shading off to a beautiful rosy red in the distance. By 5.30 p. m. the lower colors had become dark red and very brilliant. Thereafter the colors faded rapidly, and the last glow was seen at 6.10 p. m.

In the following letter, which is a reply to circular letter of December 28, 1912, attention is called to the well-known fact that brilliant twilight colors are only observed under favorable meteorological conditions:

During the summer of 1911 I spent from June 12 until September 1 in Prince Edward Island, Canada. Almost the entire summer there were brilliant pink sunsets that were very similar to those in the autumn of 1883. Previous experience in that region shows that brilliant afterglow sunsets may be expected in summer.

In 1912, from June 5 until September 7, I saw no afterglow that was brilliant, and only a few that were slightly reddish. The weather was unusually damp for the region all summer.

It would appear that the amount of moisture must have had some relation to the absence of the afterglow of the sunsets in 1912 in the above region.—Prof. C. C. TROWBRIDGE, Department of Physics, Columbia University, New York City.

There seems to be good evidence that unusually brilliant red sunsets were observed in the United States during the fall of 1912, and especially in November, and in the drier sections of the country, where conditions were especially favorable for such observations. It does not appear that the twilight colors have been markedly different from those of other years except for an increase in intensity, and in some cases an increase in duration. While the purple or rose-colored glow that has been observed to overspread the sky a short time after sunset or previous to sunrise has been a prominent feature of the displays, it has not been comparable with the afterglows observed in 1883.[1]

Atmospheric turbidity in Europe in 1912.—The reader is referred to the scientific journals[2] for details of the many observations that indicate decreased atmospheric transparency in Europe during the latter part of 1912. Nearly all the writers fix the date of the first appearance of the haze between June 20 and 27; Dr. L. Steiner, however, finds evidence of unusually hazy conditions as early as May, 1912, which were intermittent in character and appeared to be connected with anticyclonic weather conditions. The intensity of the haze appeared to increase with each recurrence, until a maximum was attained in July.

In his reply to circular letter of December 28, 1912, Dr. Adolf Hnatek, of the Vienna Astronomical Observatory, places the first appearance of the haze previous to June 12. He states that since two photographic-photometric exposures on the constellation Coma Berenices, one on June 12, of 80 minutes, and the other on June 19, of 90 minutes, failed to show stars revealed by an exposure of an hour on June 3, the disturbance in the atmosphere may have had its commencement between June 6 and 12. He estimated the decrease in atmospheric transmissibility at from 10 to 15 per cent.

Observations from high Alpine peaks and from balloons indicate that the haze was confined to great heights. It seems to have diminished greatly by November, 1912, although some observers saw evidence of it at the end of the year.

Summary.—The eruption of Katmai Volcano, on June 6, 1912, was followed by a fall of volcanic ash over all of southeastern Alaska and southward into the State of Washington.

A hazy or smoky condition of the atmosphere that was first observed in the United States from June 8 to 10, but apparently did not reach its maximum intensity until June 20 to 25, was also observed in Europe and in northern Africa. In Europe it was not generally observed until after June 20, although there is evidence that it may have been present previous to June 12. In Algeria, northern Africa, there is evidence that it was present as early as June 19.

Astronomical observations, and especially astronomical photography, together with pyrheliometric measurements and records from sunshine recorders, indicate that the haze caused a marked decrease in atmospheric transparency.

Twilight colors in the United States during the fall of 1912 were more brilliant than usual and perhaps also of greater duration. The red shades were especially pronounced.

At the end of 1912 the haziness appeared to be decreasing.

MOUNTAIN SNOWFALL MEASUREMENTS.

By BENJAMIN C. KADEL, Local Forecaster, Weather Bureau.

As the irrigation systems of the country increase, the need of more accurate measurements of the water supply from the mountain snow fields becomes greater. An experience of two years' actual work in the snow fields of a portion of the Rio Grande National Forest in Mineral County, Colo., at elevations exceeding 9,000 feet, has demonstrated that the problem is not so complicated as it may appear to the casual visitor to the mountains. The apparent confusion in the distribution of the snow layer, here the bare hillside, there the deep even layer of the forest, and beyond the great timber line drifts, is, upon closer acquaintance, found to be the result of natural causes, the most important of which is the angle the slope, on which the snow lies, makes with the sun. In the high regions of the mountains the sun shines for a greater number of hours during the winter than at lower elevations because the sky is less frequently obscured by cloud, and the sun's rays are also stronger, because they

[1] The eruption of Krakatoa and subsequent phenomena. Report of the Krakatoa committee of the Royal Society, p. 340, and frontispiece.

[2] *Wolf, M.* Trübung der Atmosphäre und Dämmerungserscheinungen. Met. Zeit., July, 1912, Bd. 29, p. 339.
Busch, Fr. Eine neue optische Störung in der Atmosphäre. Met. Zeit., Aug., 1912, Bd. 29, p. 385.
Maurer, J. Atmosphärische Trübung. Met, Zeit., 1912, Bd. 29, p. 385, 588.
Hildebrandsson, H. H. Atmosphärische Trübung in Schweden. Met. Zeit., Sept., 1912, Bd. 29, p. 442.
Stentzel, A. Die neue Dämmerungsstörung. Met. Zeit., Oct., 1912, Bd. 29, p. 485.
Hahn, F. Die atmosphärische Störung im Sommer 1912. Met. Zeit., Oct., 1912, Bd. 29, p. 488.
Weigand, Albert. Die anomale Trübung der Atmosphäre. Met. Zeit., Nov., 1912, Bd. 29, p. 532.
Marten, W. Schwächung von Sonnenstrahung und Sonnenscheindauer durch eine atmosphärische Trübung im Sommer 1912. Met. Zeit., Nov., 1912, Bd. 29, p. 533.
Duschnitz, Ign. Paul. Trübung des Himmels in Südtirol. Met. Zeit., Nov., 1912, Bd. 29, p. 534.
de Quervain, Dr. A. Merkwürdiger Himmelsanblick im Inneren Grönlands im Sommer 1912. Met. Zeit., Dec., 1912, Bd. 29, p. 587.
Hellmann, G. Die Ursache der ungewöhnlichen Trübung der Atmosphäre im Sommer 1912. Met. Zeit., Jan., 1913, Bd. 30, p. 34.
Steiner, Dr. L. Zur atmosphärischen Trübung im Sommer 1912. Met. Zeit., Jan., 1913, Bd. 30, p. 36.
Shaw, W. N. Peculiar appearance of the sky during the summer, 1912. Qr. J. R. Met. Soc., Oct., 1912, v. 38, p. 312.
Jensen, Dr. Chr. Über die grosse atmosphärisch-optische Störung von 1912. Reprint from Mitteil. d. Vereinig. v. Freunden d. Astron. u. kosm. Physik, Berlin.